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Report No. CG-D-57-81

LEVEL II

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ELECTRICAL HAZARD PROTECTION OF TANK VESSELS WHILE MOORED TO SHORE FACILITIES

ROYAL HARRISON
CARL THIELE
DON HOFF

FINAL REPORT

MAY 1981

TASK I

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Prepared for

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
Office of Research and Development
Washington, D.C. 20593

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16. Abstract

The scope of this task is limited to tanker/terminal operations involving the transfer of liquid flammable cargoes. A literature search and review has been conducted to collect available information pertinent to the electrical hazards related to the ship to shore transfer of flammable cargoes. The literature search revealed that a great amount of work has been accomplished in the area of static charge hazards, however very little has been done to characterize the nature of stray currents. It has not been feasible to produce mathematical stray current models using the available literature. A review of current practices of various operators was accomplished, mostly by observation and interview. Specific documents dealing with electrical hazards were not available at the terminals. The personnel involved with cargo transfer at the terminals are, in general, only vaguely aware of the nature and hazards of stray currents and static charges. Instrumentation was designed and fabricated for the measurement of stray currents. The instrumentation will measure voltage, current, and the capability of the tanker/terminal circuit to produce an arc when the circuit is opened. The measurement of stray current was accomplished at several terminals. In some cases, significantly high current flows capable of producing arcs were observed between the tanker and terminal. In one case, the presence of two bonding cables and a connected loading arm did not prevent arcing.

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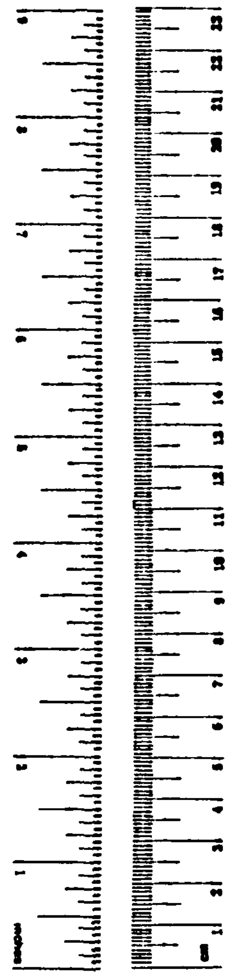
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

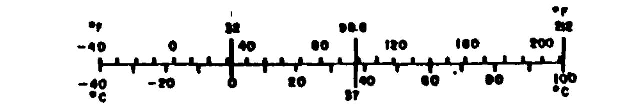


FIGURE 3. METRIC CONVERSION FACTORS.

Electrical Hazard Protection of Tank
Vessels While Moored to Shore Facilities

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(JPL Publication 5030-503)

May 15, 1981

Task 1 Report

Prepared for

United States Department of Transportation
United States Coast Guard
Office of R&D
Washington, DC 20590

Prepared by the Jet Propulsion Laboratory, California Institute of Technology, for the United States Department of Transportation, United States Coast Guard.

FOREWORD

The Jet Propulsion Laboratory, under contract to the United States Coast Guard, has undertaken the investigation of electrical hazard protection of liquid flammable cargo vessels while moored to shore facilities. In the performance of Task I, JPL has conducted a literature review and problem definition, conducted a survey of current practices, performed preliminary measurements of stray currents, and developed a test methodology.

This is the final report for Task I.

The general scooe of Task II consists of data collection, reduction, mathematical models, and analysis. The Task II plan will be submitted as a separate document.

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SECTION I

INTRODUCTION

The scope of this task is limited to tanker/terminal operations involving the transfer of liquid flammable cargoes.

A literature search and review has been conducted to collect available information pertinent to the electrical hazards related to the ship to shore transfer of flammable cargoes. The literature search revealed that a great amount of work has been accomplished in the area of static charge hazards, however very little has been done to characterize the nature of stray currents. It has not been feasible to produce mathematical stray current models using the available literature.

A review of current practices of various operators was accomplished, mostly by observation and interview. Specific documents dealing with electrical hazards were not available at the terminals. The personnel involved with cargo transfer at the terminals are, in general, only vaguely aware of the nature and hazards of stray currents and static charges.

Instrumentation was designed and fabricated for the measurement of stray currents. The instrumentation will measure voltage, current, and the capability of the tanker/terminal circuit to produce an arc when the circuit is opened.

The measurement of stray current was accomplished at several terminals. In some cases, significantly high current flows capable of producing arcs were observed between the tanker and terminal. In one case, the presence of two bonding cables and a connected loading arm did not prevent arcing.

A great amount of experimental work has been accomplished by various organizations to characterize the nature of static charge hazards. The conditions that produce electrostatic charges and the spark mechanisms are well known. In view of this large body of work, it did not seem appropriate in Task I to repeat measurements that have already been made. Some observations as to how this information can be used to improve the safety record of some terminals is presented herein.

The cooperation of the oil company terminals and tanker operators has been excellent.

SECTION II

LITERATURE SEARCH AND REVIEW

The literature search activity commenced on 17 December 1979 with the submission of a set of key words to the JPL library. The key words submitted were as follows:

Tank Vessels on docking and at dock	Electrical hazards
Static electricity	Static
Static charge	Sparking
Stray current	Arcing
Bonding	Grounding
Insulating	Cathodic protection
Ignition hazard	Inerting
Instrumentation	Ignition requirements
Spark discharge	Bonding cables
Air/Fuel Ratio	Venting
Stray potentials	Flame propagation

The operation of these key words resulted in the receipt of 346 titles and abstracts. Of these 346 titles and abstracts, 42 were considered pertinent to the project. Of the 42 documents ordered 32 were found to be of some value in the performance of this task. The titles are listed in Appendix A.

Ten Marine Casualty or accident reports were received during the search, but proved to be of little value to this project.

Documents pertaining to static charges listed many references dealing with the various mechanisms for producing the charges, with the tank washing systems receiving a great deal of attention.

Of particular interest in understanding the nature of the static charge hazards is "Appendix F of the *International Oil Tanker and Terminal* Safety Guide, 2nd Edition 1974".

Documents dealing with the stray current hazards are useful in demonstrating the existence of stray currents, however none of the experiments described in the documents provided sufficient information to produce a clear understanding of the nature of the conditions that produce the stray currents.

Very little information of value concerning gas inerting systems and vapor recovery systems was received during the literature search.

SECTION III

STATIC CHARGE REVIEW

A. STATIC CHARGE CONDITIONS

The characterization of the nature of the hazards of static charges has been accomplished numerous times by many investigators. The conditions that must exist to produce an ignition are mentioned in a number of the documents obtained in the literature search and are repeated here.

(1) There must be a means of electrostatic charge generation.

(2) There must be a means of accumulation of an electrostatic charge capable of producing an incendiary spark.

(3) There must be a means of discharging the accumulated electrostatic charge in the form of an incendiary spark, i.e., a spark gap.

(4) There must be an ignitable vapor-air mixture in the spark gap.

Control of any one of the aforementioned conditions can reduce or eliminate the possibility of an ignition caused by an electrostatic discharge.

B. STATIC CHARGE CONTROLS

Some obvious controls that reduce the hazards of pumping static accumulators are as follows:

(1) Require the use of flow meters so that when a low flow rate is necessary (1 meter/second) it can be easily maintained.

(2) Avoid the use of long lengths of non-conductive hoses and pipes such as nitrile rubber and PVC pipe. Fifty feet is the maximum recommended length.

(3) Filters must be at least 30 seconds upstream at maximum flow rate.

(4) Use anti-static additives where possible.

(5) It is possible to prevent the accumulation of a charge on the surface of a liquid in a tank by the introduction of an ionizing

radiation that would make the air sufficiently conductive. It appears that a low level beta emission, not hazardous to humans would accomplish this. However, this might not be practical for other reasons.

(6) A spark gap will always exist between the structure of the tank and the surface of the liquid. Floating objects will aggravate this situation.

(7) The use of plastic or PVC pipes inside the tank is not recommended. A highly charged liquid flowing through the plastic pipe will cause a rapid charge accumulation on the pipe. While it is generally accepted that a charged plastic of very low electrical conductivity will not produce a spark, there is some evidence that when a highly charged liquid is in contact with the inner wall that a discharge can occur. It has been observed in aircraft armored fuel hoses that static discharges through the wall to the armor have sufficient energy to create a minute hole through the wall. This was observed in teflon hose that required a potential across the hose wall of 80 KV to produce the breakdown.

(8) Ignitable vapor-air mixture can be prevented. The ideal system appears to be one where the loading and off-loading of the tank vessel is accomplished by a completely closed system. The terminal or vessel must provide a gas inerting system, a vapor recovery system, and the means for ullaging that will not permit vapor venting.

There is no evidence that there is any static charge hazard to a tank vessel being off loaded.

C. SEATTLE ACCIDENT OBSERVATIONS

In September 1980, an opportunity was presented to inspect a barge in Seattle that had been involved in explosion and fire while loading gasoline. The number 2 port had been loading about 6 minutes when the ignition occurred. The loading circuit was quite long and consisted of a filter some distance upstream, 300 ft. of nitrile rubber lined flexible hose, about 4 ft. of steel pipe in the barge manifold, and 45 ft. of 4" I.D. schedule 40 PVC pipe in the tank. If the initial loading rate was high, the charge accumulated by the gasoline when passing through the filter may not have relaxed due to the excessive length of non-conductive hose and pipe. There was no flow meter in the circuit. A comment by a barge man was that "the noise made by the gasoline going into the tank was unusual". The unusual noise could be attributed to a high flow rate, or that the PVC pipe was broken near the top of the tank. The tank was clean, newly painted, and contained a normal atmosphere before loading. It was noted that scaffold support brackets had been left attached to the bulkheads at a height of about 6 ft. A piece of rubber hose about 3" long and 1" in diameter was found in the tank. It is not likely that this piece of hose made any contribution to the accident.

The PVC pipe was broken in two places. One break was a few inches from the connection to the steel pipe at the top of the tank and the other break was about 15 ft. from the bottom end of the pipe. The pipe crossed the tank on a diagonal from the manifold to a corner at the bottom and terminated about 3" off of the bottom. There was no splash baffle. The ullage pipe was reported to have been closed. The vent had flame arresters installed. The damage to the tank was moderate. The overhead and bulkheads were bulged outward and holes torn where the internal support structure was pulled loose. The internal support structure was badly distorted. It was not possible to determine where in the tank the ignition took place.

Based on these observations only, and not having had access to any testimony concerning the accident, the most likely causes of the ignition are listed in their order of probability:

(1) An electrostatic discharge from a charged mist of gasoline to the internal structure. This could be caused by an excessive initial flow rate. It is very likely that an explosive vapor/air mixture was present in the tank, as pumping had been underway for only six minutes.

(2) An electrostatic discharge caused by top filling due to a broken PVC pipe. The gasoline was probably highly charged when entering the tank, and spraying from a broken pipe at the top of the tank

would increase this charge to the point that an electrostatic discharge would be very likely to happen.

(3) An electrostatic discharge through the wall of the PVC pipe to a pipe support bracket. This is not very likely due to the short time from the start of flow. The 1/4" thick wall of the PVC pipe would require about 135 KV across it to produce a breakdown.

(4) An electrostatic discharge from the surface of the PVC pipe to the support structure. It is difficult to produce an incendive spark in this manner, but it can happen. An investigation into this possibility with PVC pipe will be proposed.

(5) After visiting the terminal it does not appear that an external source of ignition was likely. The wire wrap in the flexible hose was connected at one end only, although it was not clear which end. No bonding cables were used. A dock worker stated that a light breeze was blowing.

D. GREENVILLE ACCIDENT OBSERVATIONS

Another barge accident in Greenville, Mississippi was discussed by telephone with the Coast Guard investigator. The barge tank was being ventilated by an electrically powered blower. The tank had contained gasoline. The fumes driven from the tank assumed alarming proportions in the vicinity and the blower was turned off. At this moment, or a few seconds later, the ignition occurred. The most likely source of ignition was a static charge on the fan blades. The means of charge generation was the high velocity passage of air over the fan blades. The means of charge accumulation was that the rotor floated on oil and was isolated from ground while rotating at high speed. An ignitable vapor/air mixture was present. The spark possibly occurred when the rotor settled into electrical contact when the power was turned off. Another possible ignition source was a ground wire that was wrapped around one of the match lugs. The ground wire may have been loose and an inductive kick when the motor was turned off might have produced a spark. A third possible ignition source was the power switch for the motor. It was not an explosion proof switch and was located 30 or 40 ft. away on the dock.

A stray current arc cannot be ruled out in this accident.

It appears that the use of flow meters, gas inerting systems, and vapor recovery systems would have prevented most of the barge accidents mentioned in the literature. The accidents described herein would also have been prevented by the use of these systems.

SECTION IV

STRAY CURRENT REVIEW

The existence of a stray current hazard at the tank vessel/terminal interface has been known for many years. The measures adopted by various terminals to reduce the ship to shore potentials range from ignoring the problem, to insulating, to the application of multiple bonding cables, or a combination of insulating and bonding. Several papers obtained during the literature review demonstrate the presence of heavy current flows between the tank ship and terminal and present an analysis of the sources of the stray currents. Four papers in particular, have provided some insight to the problem. They are:

"Electrical Safety at Docks for Ships Transferring Hazardous Cargos."

"The Bonding of Ships to Cathodically Protected Docks."

"Review of Bonding Practices of Ship to Shore Facilities Handling Petroleum Products."

"Electrical Significance of Cathodic Protection on Hazardous Area Steel Docks."

None of the aforementioned papers deal in any depth with the interactions of ship and terminal corrosion protection systems.

The preliminary measurements accomplished by JPL, and described herein, have demonstrated complexities not previously discussed.

The paper entitled, "The Bonding of Ships to Cathodically Protected Docks", by J.A. Lehmann, contains descriptions of dock protection systems, and a simple model of current flow through the bonding cable. The preliminary JPL experiments have indicated that there are many variables not previously considered. These variables will have to be considered in any mathematical modeling. The large number of possible ship/terminal combinations indicate that there must be several models in order to adequately describe the stray current hazards. Table I on the following page, lists possible ship/terminal combinations. The areas that have been examined are indicated by the test numbers.

TERMINAL CORROSION PROTECTION SYSTEMS	SHIP CORROSION PROTECTION SYSTEMS		
	IMPRESSED CURRENT SYSTEM	GALVANIC ANODE SYSTEM	NO PROTECTION
IMPRESSED CURRENT SYSTEM	TESTS: 1,2,3,6, & 8		
GALVANIC ANODE SYSTEM			
REMOTE BED IMPRESSED CURRENT SYSTEM			
NO PROTECTION		TESTS: 4 AND 5	TEST: 7

Table 1.

Ship/Terminal Combinations

SECTION V

STRAY CURRENT MEASUREMENT EXPERIMENTS

A. EXPERIMENTS AT ARCO PIER 118

1. Arco Procedure for Mooring, Connecting Transfer Lines, and Pumping at Pier 118, Long Beach, CA

Step 1

(1) Tanker brought to dock by tugs.
(2) Springlines and mooring lines attached.
(3) Ship and shore manifolds aligned using spring lines.

(Comment)

a. During these operations there are supposedly no low resistance electrical contacts made between ship and shore.
b. The ship hull contacts only rubber fenders on the outermost dock pilings
c. The spring lines are wire but have a rope pennant at the dock end.
d. The mooring lines are rope.
e. It has been noted that when spring lines go limp they rest on some iron slip cylinders on the dock. It is not known whether these have a low resistance path to ground. This may be one of the places where dock operators say they have seen arcs.

Step 2

The ARCO bonding cable attached to the shore manifold (BC1) is attached by C-clamp to the port gunwale at a point close to the ship manifold. (There is a 100 ampere d.c. meter in BC1 and an enclosed switch which is open when the attachment is made, and then closed.)

(Comment)

a. The resistance of BC1 was measured at 0.024 ohms using a Kelvin Bridge.
b. The C-clamp connection is not good. The gunwales are usually well painted and good contact depends on a pointed end on the screw part of the C-clamp. Current would have to flow through the rusty threads.

Step 3

The gang plank is installed. (Only after this can anyone board or leave the tanker.)

(Comment)

The dock end of the gang plank is equipped with insulated wheels.

Step 4

The ARCO bonding cable on the next pier aft (BC2) is attached to the port gunwale just opposite to the pier. This is probably between 150-200 ft. aft of BC1.

BC2 is just like BC1 and is connected to the pier grounding system.

(Comment)

a. The resistance of BC2 has not been measured.
b. See comment b. for Step 2.

Step 5

The ship to shore telephone is plugged in.

(Comment)

This is not supposed to make a low resistance path between ship and shore.

Step 6

The loading arms transfer lines are connected.

(Comment)

The chicksan flanges are not bolted to the ship flanges but clamped to them by lugs. During connection operations, many make and break contacts occur. Arcing may have been observed by operators during this procedure.

Step 7

Pumping is started.

(Comment)

a. The pumps are steam turbine driven. They are first brought on line pumping through piping internal to the hull.
b. The valves are then opened and the pumps brought up to full pressure.
c. The pressure in the hull piping is about 125-140 psi, but drops to about 40 psi in the shore manifold because of the constrictions in the loading arms.

2. ARCO Pier 118 Test Results

a. TEST 1, September 12, 1980
ARCO ALASKA
Piers 117, 118, 119, Long Beach, CA

Each pier has its own impressed cathodic protection system. These are not servo controlled. They use 3 phase rectifiers operating at +4 volts, anodes to shore ground. The currents are 11 amperes at Pier 117, 15 amperes at Pier 118, and 19 amperes at Pier 119. Each pier has two anodes hanging in the water, one on each side, fed from the same rectifier.

The ship has two impressed cathodic protection systems, one forward, another aft. They use 3 phase rectifiers and are servo controlled.

A 360 Hz ripple voltage was always present between ship and shore. Since the ship and shore power sources were not synchronous, there were beats in the observed signal.

The unidirectional voltage between ship and shore was very unsteady. The ship was negative with respect to shore, therefore electrons were flowing to the shore.

No arcing was detected.

Procedure Step No.	Ship to Shore Voltage (Volts)	Ship to Shore Current (Amperes)	Source Resistance (Ohms)
1 Moored	-0.094	-4.1	0.014
2 Bonding Cable 1	-0.097	-4.7	0.012
3 Gangplank			
4 Bonding Cable 2	-0.095	-4.9	0.010
5 Telephone			
6 Three uninsulated loading arms all connected	-0.074	-5.0	0.006
	-0.032	-2.0	0.007
	-0.036	-3.0	0.003
	-0.060	-5.0	0.003
7 Start pumping	-0.019	-2.0	0.001
Full pressure	-0.012	-1.0	0.003

b. TEST 2, September 22, 1980
ARCO JUNEAU
Piers 117, 118, 119, Long Beach, CA

Each pier has its own impressed cathodic protection system. These are not servo controlled. They use 3 phase rectifiers operating at +4 volts, anodes to shore ground. The currents are 11 amperes at Pier 117, 15 amperes at Pier 118, and 19 amperes at Pier 119. Each pier has two anodes hanging in the water, one on each side, fed from the same rectifier.

The ship has two impressed cathodic protection systems, one forward, another aft. They use 3 phase rectifiers and are servo controlled.

A 360 Hz ripple voltage was always present between ship and shore. Since the ship and shore power sources were not synchronous, there were beats in the observed signal.

The unidirectional voltage between ship and shore was very unsteady. The ship was negative with respect to shore, therefore electrons were flowing to the shore.

The ship connection to the JPL bonding cable was obviously bad, so no arcing was detected. Extensive repairs were to be made to the manifolds and it would be several hours before loading arms would be connected, so the test was terminated.

Procedure Step No.	Ship to Shore Voltage (Volts)	Ship to Shore Current (Amperes)	Source Resistance (Ohms)
1 Moored	-0.336	-3.0	0.103
	-0.369	-4.0	0.083
2 Bonding Cable 1	-0.366	-4.0	0.082
3 Gangplank			
4 Bonding Cable 2	-0.316	-4.0	0.070
	-0.254	-3.0	0.076
	-0.236	-3.0	0.070
	-0.239	-3.0	0.070
5 Telephone			

c. TEST 3, October 4, 1980
ARCO CALIFORNIA
Piers 117, 118, 119, Long Beach, CA

Each pier has its own impressed cathodic protection system. These are not servo controlled. They use 3 phase rectifiers operating at +4 volts, anodes to shore ground. The currents are 11 amperes at Pier 117, 15 amperes at Pier 118, and 19 amperes at Pier 119. Each pier has two anodes hanging in the water, one on each side, fed from the same rectifier.

The ship has two impressed cathodic protection systems, one forward, another aft. They use 3 phase rectifiers and are servo controlled.

A 360 Hz ripple voltage was always present between ship and shore. Since the ship and shore power sources were not synchronous, there were beats in the observed signal.

The unidirectional voltage between ship and shore was very unsteady. The ship was negative with respect to shore, therefore electrons were flowing to the shore.

Arcing was detected (*) until loading arm 3 was connected.

Procedure Step No.	Ship to Shore Voltage (Volts)	Ship to Shore Current (Amperes)	Source Resistance (Ohms)	
1 Moored	-0.456	-20.9	0.013	*
2 Bonding Cable 1	-0.373	-18.1	0.012	*
	-0.334	-18.0	0.010	*
3 Gangplank				
4 Bonding Cable 2	-0.278	-14.8	0.010	*
5 Telephone				
Had to move ship connection to an adjacent flange.	-0.249	-14.2	0.009	*
6 Loading Arm 1	-0.280	-15.0	0.010	*
Loading Arm 2	-0.216	-12.2	0.009	*
Loading Arm 3	-0.135	- 9.2	0.006	
7 10 psi	-0.105	- 7.0	0.006	
40 psi	-0.069	- 5.0	0.005	

d. TEST 6, November 6, 1980
ARCO JUNEAU
Piers 117, 118, 119, Long Beach, CA

Each pier has its own impressed cathodic protection system. These are not servo controlled. They use 3 phase rectifiers operating at +4 volts, anodes to shore ground. The currents are 11 amperes at Pier 117, 15 amperes at Pier 118, and 19 amperes at Pier 119. Each pier has two anodes hanging in the water, one on each side, fed from the same rectifier.

The ship has two impressed cathodic protection systems, one forward, another aft. They use 3 phase rectifiers and are servo controlled.

A 360 Hz ripple voltage was always present between ship and shore. Since the ship and shore power sources were not synchronous, there were beats in the observed signal.

The unidirectional voltage between ship and shore was very unsteady. The ship was negative with respect to shore, therefore electrons were flowing to the shore.

Arcing was detected (*) until voltage dropped to -0.160 volts.

Procedure Step No.	Ship to Shore Voltage (Volts)	Ship to Shore Current (Amperes)	Source Resistance (Ohms)	
1 Moored	-0.299	-14.0	0.013	*
2, 3, 4 and 5	-0.241	-12.0	0.011	*
(Bonding cables 1 and 2,	-0.201	-10.0	0.011	*
gangplank, & telephone)	-0.160	- 9.3	0.009	
	-0.152	- 8.6	0.010	
Ship impressed cathodic protection off	-0.114	- 6.5	0.009	
Back on	-0.183	- 8.9	0.012	
6 Loading Arm 1	-0.137	- 8.6	0.007	
Loading Arm 2	-0.097	- 6.4	0.007	
Loading Arm 3	-0.103	- 7.4	0.005	
7 30 psi	-0.042	- 3.3	0.004	
60 psi	-0.033	- 2.0	0.008	

e. TEST 8. February 5, 1981
ARCO ANCHORAGE
Piers 117, 118, 119, Long Beach, CA

Each pier has its own impressed cathodic protection system. These are not servo controlled. They use 3 phase rectifiers operating at +4 volts, anodes to shore ground. The currents are 11 amperes at Pier 117, 15 amperes at Pier 118, and 19 amperes at Pier 119. Each pier has two anodes hanging in the water, one on each side, fed from the same rectifier.

The ship has two impressed cathodic protection systems, one forward, another aft. They use 3 phase rectifiers and are servo controlled.

A 360 Hz ripple voltage was always present between ship and shore. Since the ship and shore power sources were not synchronous, there were beats in the observed signal.

The unidirectional voltage between ship and shore was very unsteady. The ship was negative with respect to shore, therefore electrons were flowing to the shore. No arcing was detected.

Procedure Step No.	Ship to Shore Voltage (Volts)	Ship to Shore Current (Amperes)	Source Resistance (Ohms)
1 8:40 AM	-0.220	-10	0.013
8:45 AM	-0.220	-12	0.010
2 8:50 AM			
Bonding Cable 1	-0.220	-12	0.010
3/4/5 8:52 AM			
Gangplank			
Bonding Cable 2	-0.192	-10	0.011
9:00 AM	-0.140	- 8	0.009
9:10 AM	-0.126	- 7	0.009
Ship connection moved from manifold to deck railing			
9:15 AM	-0.116	- 7	0.008
9:45 AM	-0.116	- 7	0.008
6 9:45 AM	-0.089	- 5	0.009
Loading Arm 1			
9:50 AM	-0.074	- 4	0.010
Loading Arm 2			
9:55 AM	-0.062	- 4	0.007
Loading Arm 3			
10.05 AM	-0.048	- 4	0.003
Loading Arm 4			

Pumping would not be started for several hours. Test terminated.

3. <u>Discussion of Tests 1, 2, 3, 6, and 8</u>

The ARCO CALIFORNIA, JUNEAU, ALASKA, and ANCHORAGE have two impressed cathodic systems, one forward and one aft. They are servo-controlled using a half-cell reference. Their rectifiers are 3-phase and the ripple from them was always detectable, therefore they were on.

Each pier has its own impressed system. Two anodes hang into the water, one each side as shown in Figure 1. These are connected together to the +4 volt side of a 3-phase rectifier whose negative side is connected to those parts of the dock being protected. Currents between 15 and 20 amperes are drawn. These systems are not servo-controlled. The ripple from them beating with that from the ship systems could be seen at all times, therefore they were on.

A ground wire was welded to the base piping of the shore manifold. The instrumentation shore cable was connected to a flange on this piping. On the tanker, the instrument cable was connected to a manifold. During Test 8 this connection was moved to a railing welded to the deck nearby. This made no difference in the resulting measurements.

In Test 2, the ship connection was not a good one and it was not possible to change due to the pumping activities. Although the voltage was relatively high, the contact resistance prevented a high current flow through the instrument cable.

The tankers were negative with respect to shore ground. Electrons flowed from ship to shore.

All readings were, usually, very unsteady. Large sudden changes often occurred.

Two bonding cables were used and no effort to insulate the loading arms was made. The measured resistance of one of the cables (BC1) was 0.024 ohms. The C-clamp connections, made to the gunwales, were not electrically sound.

In Tests 3 and 6 where arcing occurred, connecting the bonding cables did not stop it. In Test 2, arcing would have occurred had the connection been good and the bonding cables would not have stopped it.

In Test 3 where the voltage was very high to begin with, arcing still occurred after both bonding cables and two supposedly uninsulated loading arms were connected.

Voltages are plotted against total circuit resistance for Tests 1, 3,

6, and 8 in Figure 2. This figure demonstrates how voltage and resistance decrease dramatically with time. It is particularly interesting that the effective circuit resistance approaches that of the instrument bonding cable.

The behavior and general instability of the readings are believed to be caused by the ship servo-control trying to operate when the hull is near to the shore facilities and the ocean bottom, and bonded to shore ground. The nature of this interaction will require further investigation.

From the graph it would appear arcing never occurs at voltages less than about 0.2 volts. This is not necessarily so. If the bonding cable, which is in series with the arc detector, had been only 0.001 ohms, arcing might have occurred at much lower voltages because the effective source resistance was coming down as the voltage was reducing.

Three electrodes were suspended in the water at the point shown in Figure 1 when no tanker was at the dock. The voltages with respect to shore ground were very steady.

Copper +0.670
Iron +0.422
Aluminum +0.042

The pier impressed cathodic protection systems were on. The 360 Hz ripple was present and steady. The electrodes were in the ion current path from these anodes to dock structure, therefore they are not native galvanic potentials.

Evidently the unsteady readings and peculiar behavior when a tanker is at dock are due to the tanker system servo.

O POSITION OF PIER IMPRESSED CATHODIC PROTECTION ANODES HANGING IN WATER.

△ POSITION WHERE ELECTRODES WERE SUSPENDED IN WATER.

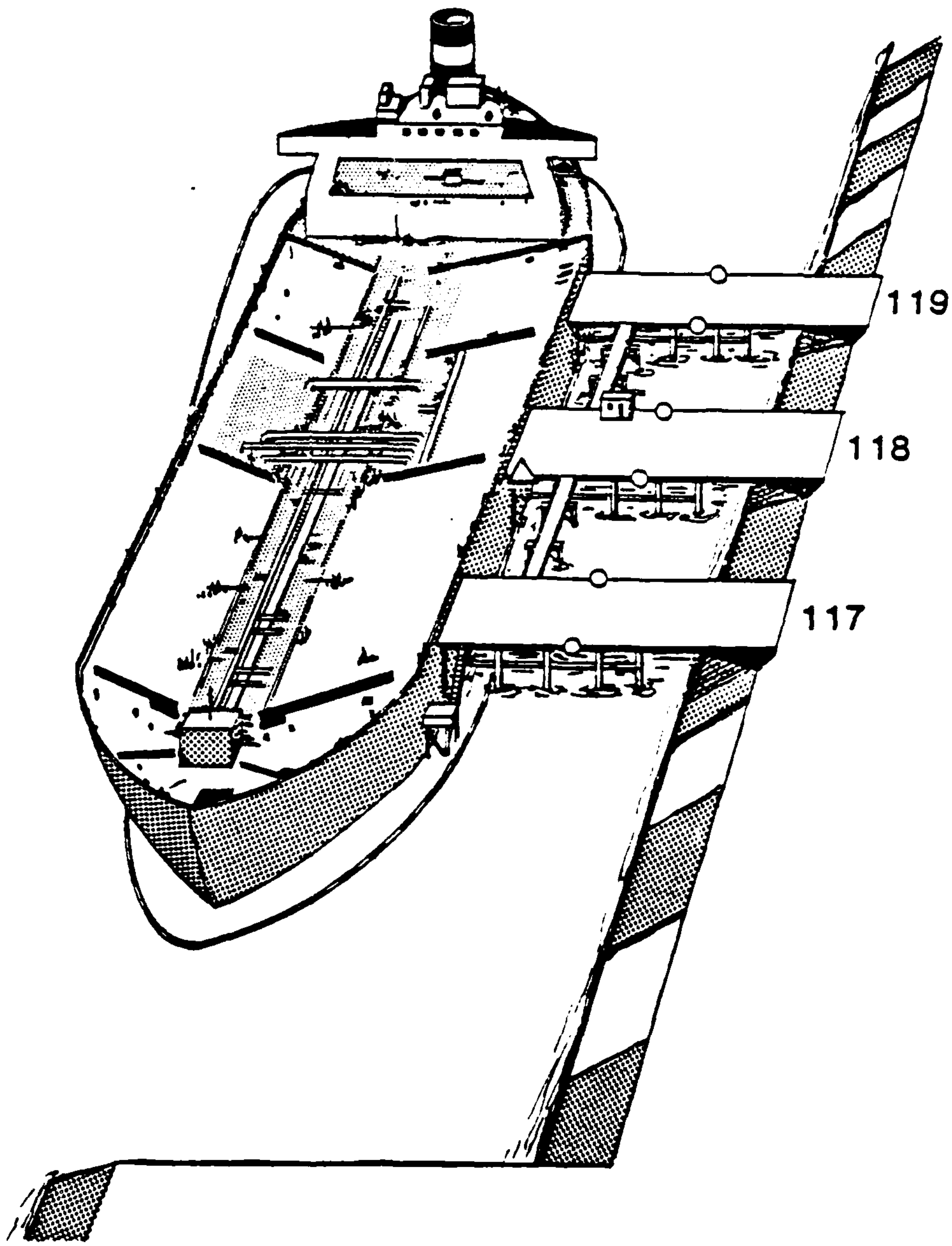

Figure 1

PIERS 117, 118, 119, LONG BEACH, CA.

ARCO PIER 118 TEST RESULTS

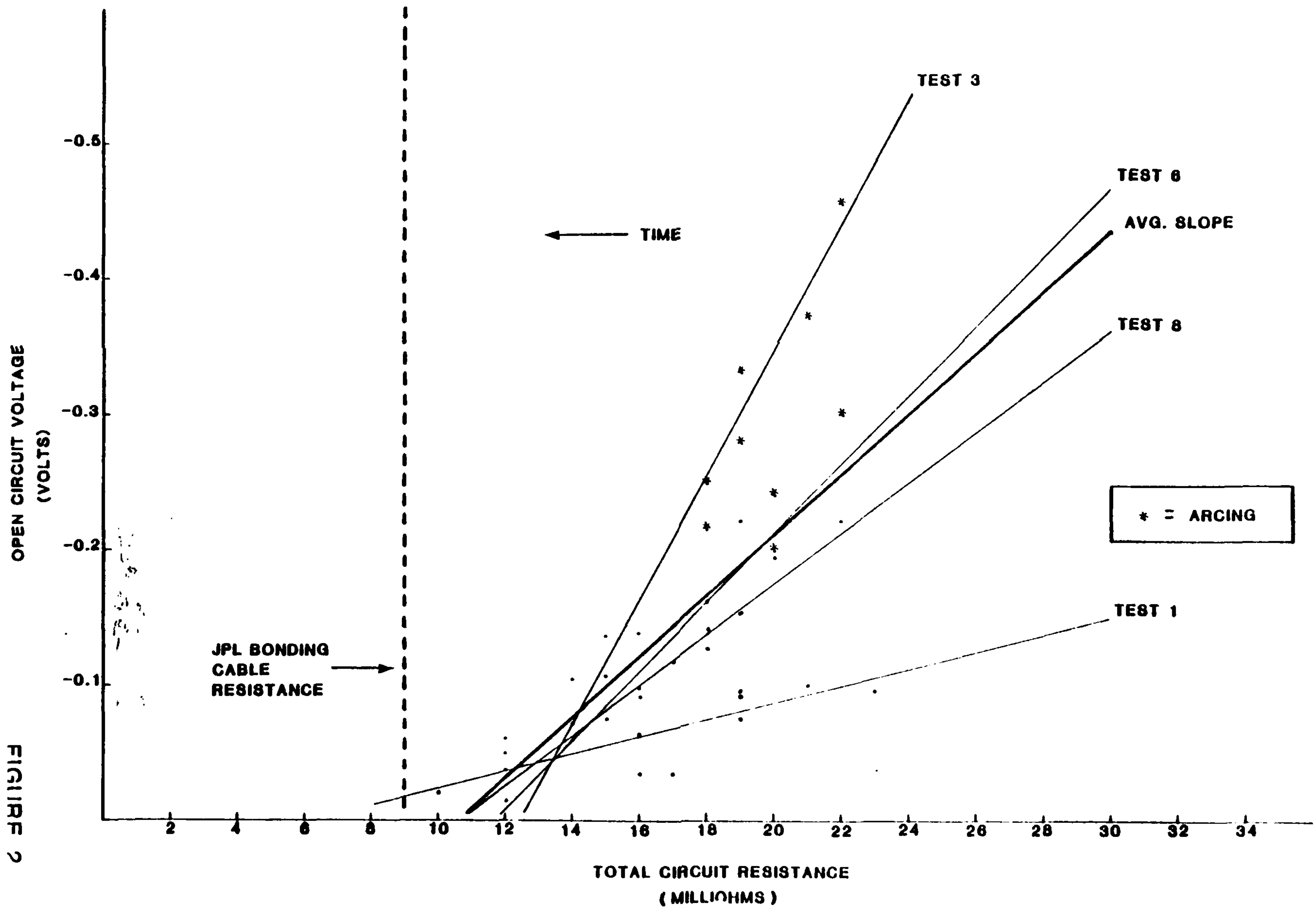

FIGURE 2

B. EXPERIMENTS AT TEXACO TERMINALS

1. Texaco Procedure for Mooring, Connecting Transfer Lines, and Pumping at Berths 84 and 86, Long Beach, CA

Step 1

(1) Tanker brought to dock by tugs.
(2) Spring lines and mooring lines attached.
(3) Ship and shore manifolds aligned using spring lines.

(Comment)

a. The ship hull contacts the wooden dock pilings.
b. The spring lines are wire and fastened to cleats on the dock whose conductivity to ground and the water mass are not known.
c. The mooring lines are rope. No bonding cables are used.

Step 2

The gang plank is installed and the telephone connected.

(Comment)

a. The dock end of the gang plank is equipped with insulated wheels.
b. The telephone is not supposed to make a low resistance path between ship and shore.

Step 3

The loading arms or flexible transfer lines are connected.

(Comment)

a. There is an insulated spool piece at the ship manifold ends of the loading.
b. The flexible lines are high resistance.

Step 4

Pumping is started.

(Comments)

The pumps are turbine/electric driven.

2. TEXACO Terminal Test Results

a. TEST 4, October 21, 1980
TEXACO MINNESOTA
Berth 84, Long Beach, CA

Berths 83 through 87 have no cathodic protection systems. The ship has galvanic anode protection.

The unidirectional voltage from ship to shore was very steady. The ship was positive with respect to shore, therefore electrons flowed to the ship.

Heavy arcing was detected at all times, (*) below.

Procedure Step No.	Ship to Shore Voltage (Volts)	Ship to Shore Current (Amperes)	Source Resistance (Ohms)	
1 Moored	+0.523	+24.0	0.013	*
2 Gangplank				
3 One insulated loading	+0.514	+28.0	0.010	*
arm connected	+0.510	+26.0	0.011	*
4 60 psi	+0.489	+25.0	0.011	*
80 psi	+0.489	+26.0	0.010	*

b. TEST 5, October 27, 1980
TEXACO GEORGIA
Berth 86, Long Beach, CA

Berths 83 through 87 have no cathodic protection systems. The ship has galvanic anode protection.

The unidirectional voltage from ship to shore was very steady. The ship was positive with respect to shore, therefore electrons flowed to the ship.

Heavy arcing was detected at all times, (*) below.

Procedure Step No.	Ship to Shore Voltage (Volts)	Ship to Shore Current (Amperes)	Source Resistance (Ohms)
1 Moored	+0.307	+16.0	0.011 *
	+0.307	+16.0	0.011 *
2 Gangplank			
3 Would not hook up to flexible transfer lines for several hours. Test stopped.			

3. Discussions of Tests 4 and 5

The TEXACO MINNESOTA and GEORGIA have galvanic anode corrosion protection systems. The nature and location of the anodes have not yet been determined.

The berths have no dedicated protection systems of any kind. No ripple voltages from any impressed system that might be on the piping or tank farms were detected.

The base piping of the shore manifold is connected to a ground cable. The instrument shore connection was made to this cable. The ship connections were made to a manifold flange.

Both tankers were positive with respect to shore ground. Electrons flowed from shore to ship.

All voltages were very steady. Heavy arcs could be drawn at any time. No bonding cables are used. Insulated loading arms and flexible hoses are used. In Test 4, connecting one loading arm and proceeding to full pumping flow had no effect on the stray current source.

Tests should be made at these berths with tankers having impressed systems.

C. EXPERIMENTS AT A UNION TERMINAL

1. <u>Union Procedure for Mooring, Connecting Transfer Lines, and Pumping at Berth 46, Los Angeles Outer Harbor, CA</u>

<u>Step 1</u>

(1) Tanker brought to dock by tugs.
(2) Spring and mooring lines attached.
(3) Ship and shore manifolds aligned using spring lines.

(Comment)

a. The ship hull contacts plastic covered fenders.
b. The spring and mooring lines are fiber, but iron rope is used in picking up the spring lines.

<u>Step 2</u>

The gangplank is installed.

(Comment)

The shore end of the gangplank does not seem to be insulated.

<u>Step 3</u>

Two bonding cables are attached to the gunwhales using C-clamps.

(Comment)

a. Both cables are connected by the same switch.
b. C-clamp connections are probably not very good.

<u>Step 4</u>

Loading arms are connected. They have no insulated section in them.

<u>Step 5</u>

Pumping is begun.

2. Union Terminal Test Results

a. TEST 7, January 9, 1981
UNION SANSINENA II
Berth 46, Los Angeles Outer Harbor, CA

Berths 45, 46, 47 have no cathode protection. The UNION SANSINENA II has an impressed system, but it had failed and been turned off two days before docking.

The unidirectional voltages were very steady. The ship was negative with respect to shore ground. Electron current was from ship to shore.

No arcing was detected. No alternating voltages were detected.

Procedure Step No.		Ship to Shore Voltage (Volts)	Ship to Shore Current (Amperes)	Source Resistance (Ohms)
1/2	10:15 AM Moored. Gangplank.	-0.197	-9	0.013
3	10:40 AM Two bonding cables.	-0.202	-9	0.014
4	10:55 AM One uninsulated loading arm connected.	-0.201	-9	0.014
	10:05 AM Second uninsulated loading arm connected.	-0.199	-9	0.014
5	12:00 Full pumping.	-0.199	-10	0.011

3. Discussion of Test 7

The UNION SANSINENA II has impressed cathodic protection. It had failed and been turned off two days before docking. No rectifier ripple was detected so it seemed that it was indeed off.

Berth 46 has no dedicated protection system of any kind.

The impressed cathodic protection systems for the piping and tank farm had been off for several months. They are single phase. No ripple was detected.

The base piping of the shore manifold is supposedly connected to a special ground stake on shore. The instrument was connected to a metal flange welded to it. Ship connection was to a manifold flange.

Unidirectional voltages due to native galvanism were expected to exist between ship and shore manifolds and that it would be low. Instead the ship was at -0.2 volts with respect to shore. Electrons flowed from ship to shore ground.

Voltages from three test electrodes were measured to the shore manifold with these results.

Copper	+0.385 volts
Iron	+0.010 volts
Aluminum	-0.168 volts

It is not yet understood why the tanker was at -0.2 volts. It does not seem that polarization could have lasted that long.

No arcing was detected, which is reasonable since the circuit resistance was 0.020 ohms and the voltage only -0.2 volts.

Connecting the two bonding cables did nothing, nor did connecting two loading arms which were not purposely insulated from the shore manifold. It can be assumed that they are actually, for some reason, not a very low resistance.

Full pumping made a small change. All voltage readings were very steady.

More experiments need to be made at this location with tankers having impressed and galvanic anode protection.

SECTION VI

INSTRUMENTATION

A. DESIGN

It was anticipated that in order to measure the stray current phenomena, the instrument should have the following characteristics:

(1) Measure unidirectional (DC), pulsating unidirectional (PDC), and alternating currents (AC). These measurements to be accomplished alone, or in any combination, between ship and shore.

(2) Measure AC and DC voltages between ship and shore.

(3) Detect arcing on the break of the current circuit by a contactor.

(4) The instrument must not present an explosion hazard in the presence of flammable vapors.

A digital DC voltmeter and a capacity coupled oscilloscope were selected for the current and voltage measurements. Variable gain amplifiers with very high common mode rejection were designed and fabricated. These amplifiers are used on the inputs to the voltmeter and oscilloscope. The amplifier circuits are shown in Figure 3. An 0.001 ohm precision current shunt is used as the current measuring element.

A device that will detect an arc when the ship to shore current path is broken was designed and fabricated. A set of two manually operated contacts (blunt and sharp) were fabricated as shown in Photo 5. These contacts were placed in an optical focusing device with a photoelectric detector to sense the light emitted by an arc. The output of the detector is amplified, integrated, and displayed on a logarithmic scale meter. The detector circuits are shown in Figure 4.

All of the instruments are in a pressurized case. (Photo #1). A system block diagram is shown in Figure 5. All required power is supplied by dry batteries in another pressurized case. The cases are connected by a hose containing the power cable. (Photo #2)

The inner tube provides an additional volume of air under pressure. Air is never pumped into the system at the dock. Pressure in the system is maintained at 0.5 psi.

The instrument has been used with 100 ft. of 4/0 ship to shore cable as

shown in Figure 5. The total resistance of the instrument and cable is about 0.009 ohms. It has been found that a 50 ft. length of 4/0 cable will reach at most of the terminals visited.

Connections to ship and shore manifolds were made using copper coupons as shown in Photos #3 and #4. Contacting surfaces were always well cleaned (with one exception, Test #2).

At all terminals the shore manifold base piping was connected by welded cables to some shore "grounding" system. How these grounds are accomplished has not yet been determined.

B. OPERATION

(1) Turn on S1.

(2) Measure open circuit voltage. If not alarmingly high, (more than 1V), continue.

(3) Turn on S2. (This puts the meters across the 0.001 ohm shunt).

(4) Measure current.

$$\text{Amps} = \frac{\text{Voltage across the shunt}}{0.001}$$

(5) Determine apparent source resistance:

$$R_{\text{total}} = \frac{\text{open circuit voltage}}{\text{closed circuit current}}$$

Apparent $R_{\text{source}} = R_{\text{cable}} - R_{\text{cable and instrument}}$

With 100 ft. of 4/0 cable, $R_{\text{cable and instrument}} = 0.009$ ohms

(6) Detect arc:
Open S2. Close, then open blunt contactor. If no arc is detected, close then open, pointed contactor. No sparks ever jump the gap before contact. Arcs are drawn only on break.

(7) Turn S1 off. This removes power from the instruments.

C. FURTHER DESIGN INFORMATION

A new technology report (Appendix B) was submitted. This report contains a detailed description of the instrumentation.

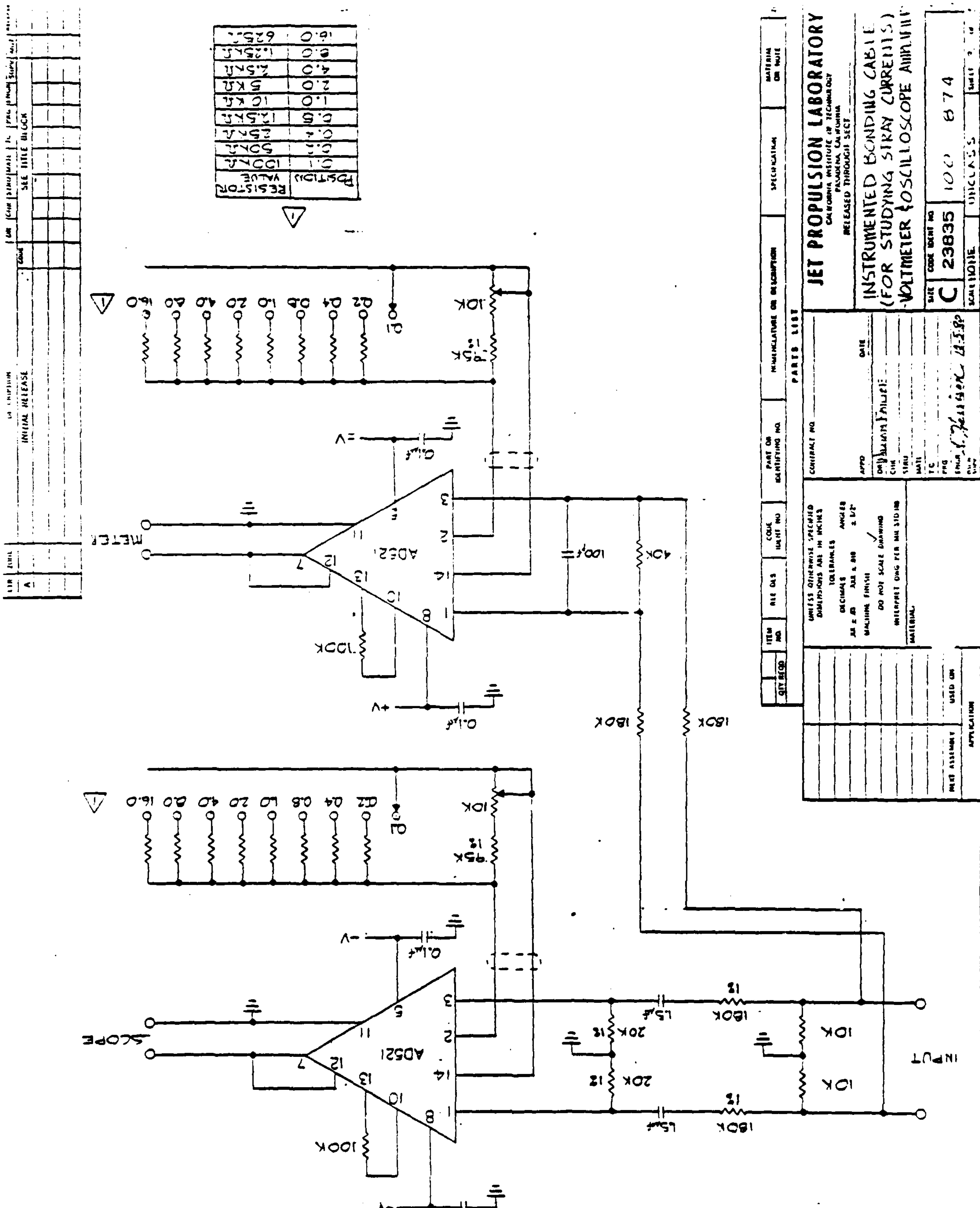
JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA
INSTRUMENTED BONDING CABLE
(FOR STUDYING STRAY CURRENTS)
VOLTMETER & OSCILLOSCOPE AMPLIFIER
23835
AD521
METER
SCOPE
INPUT
PARTS LIST

FIGURE 3

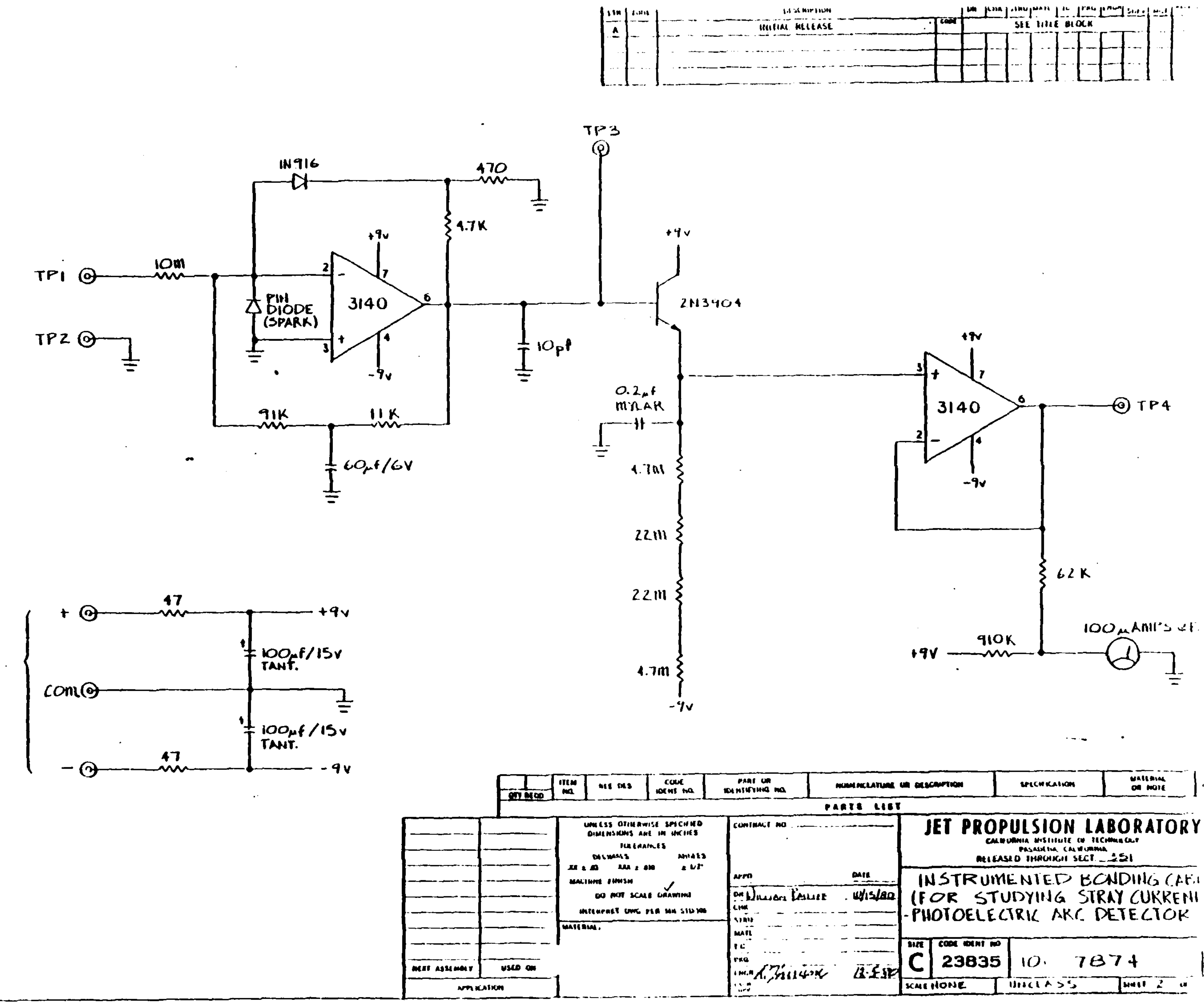
INITIAL RELEASE
SEE TITLE BLOCK
TP1
TP2
TP3
TP4
10M
IN916
470
4.7K
+9v
-9v
3140
PIN DIODE (SPARK)
91K
11K
60μf/6V
10pf
2N3904
0.2μf MYLAR
4.7M
22M
22M
4.7M
62K
910K
100μAMPS
SUPPLY
+
COM
−
47
47
100μf/15v TANT.
100μf/15v TANT.
PARTS LIST
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA
RELEASED THROUGH SECT. 351
INSTRUMENTED BONDING CABLE
(FOR STUDYING STRAY CURRENT)
-PHOTOELECTRIC ARC DETECTOR
C
23835
10. 7874
SCALE NONE
UNCLASS
SHEET 2

FIGURE 4

INSTRUMENTED BONDING CABLE FOR STUDYING STRAY CURRENTS

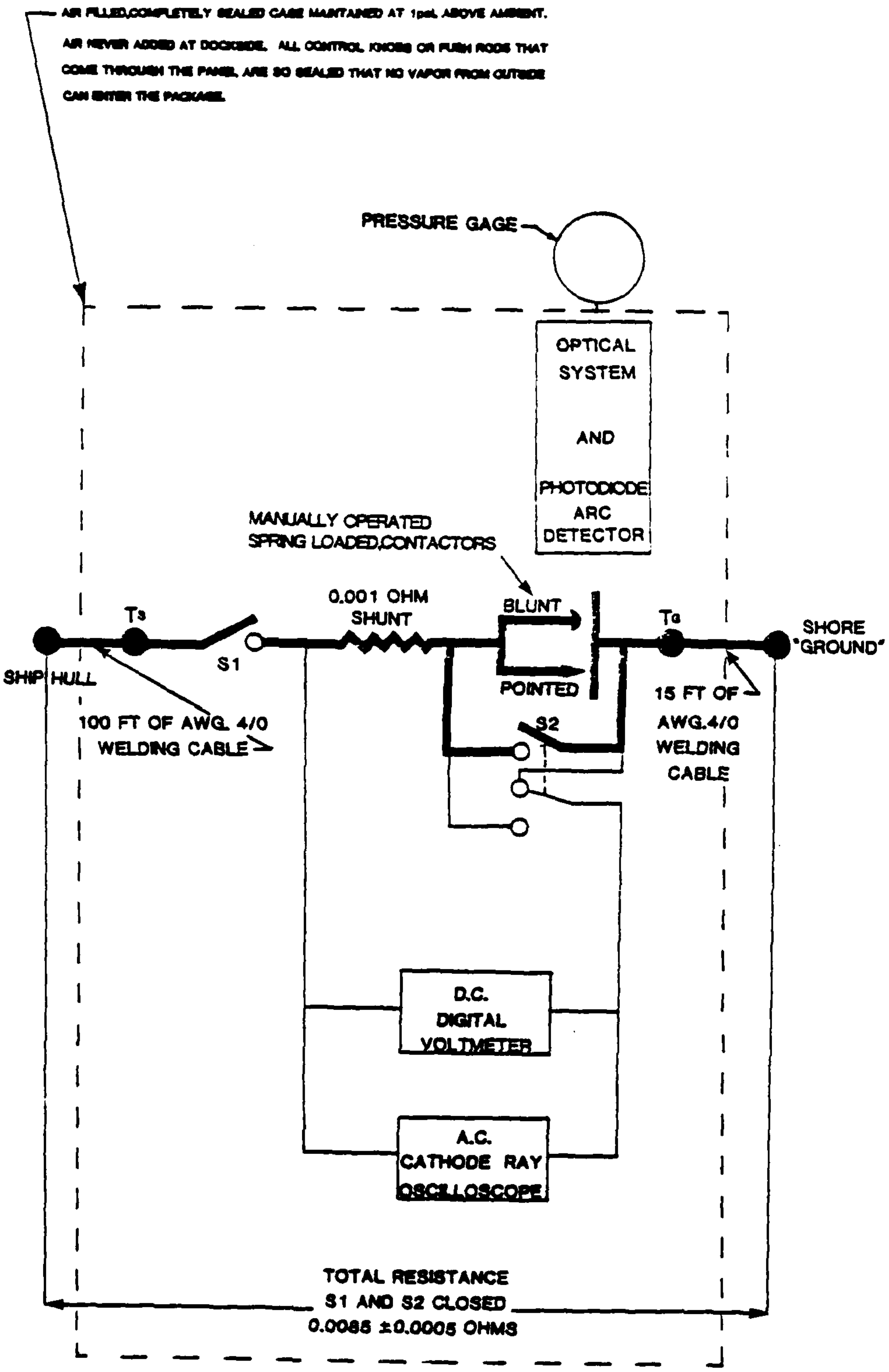

FIGURE 5

OPEN CIRCUIT MEASUREMENTS S1 CLOSED,S2 OPEN.
CLOSED CIRCUIT MEASUREMENTS S1 CLOSED ,S2 CLOSED.
ARC DETECTION S1 CLOSED,S2 OPEN,OPERATE CONTACTORS

SECTION VII

TEST METHODOLOGY FOR TASK II

A. DATA BASE

The investigations conducted in Task I have developed a number of items of information that must be obtained to create a data base for the characterizati of the stray current phenomena.

1. Terminal Information

a. Owner
b. Operator
c. Type of loading/off loading system
d. Type of corrosion protection system at the dock
   (1) Where located
   (2) Voltage and current if impressed system
   (3) Type of galvanic anode
   (4) None
e. Stray current hazard protection method
   (1) Bonding cables
   (2) Ship insulated from terminal
   (3) Bonding and insulating
   (4) Terminal manifold insulated from pipe line
   (5) None
f. Terminal grounding system
g. Pipe line corrosion protection system
   (1) Where located
   (2) Type

2. Vessel Information

a. Name
b. Registry
c. Owner
d. Displacement
e. Length and beam
f. Wetted hull area
g. Condition of bottom (how long since painted)
h. Corrosion protection
   (1) Type
   (2) Where located on hull
   (3) Current and voltage if impressed
   (4) What metal if galvanic anode

(5) None

i. Cargo

B. CRITICAL VARIABLES

The preliminary experiments in the measurement of stray currents have demonstrated the complexity of the electron and ion sources whose interactions determine the unidirectional voltages between the tank vessel and shore facilities. It has been determined that there are some critical variables that must be measured to produce the data base need for the characterization of the stray current phenomena.

1. Critical Variables to be Measured Between the Tank Vessel and Terminal

a. Voltage between terminal ground and vessel:
   (1) Open circuit.
   (2) With bonding.

b. Current flow through bonding cable.

c. Take water sample, at time of measurement, for later analysis:
   (1) Chemical composition.
   (2) Electrolyte resistance.

d. Resistance of terminal ground.

e. Resistance of ship to water.
   Electrolyte resistance, terminal ground resistance, and resistance of ship to water can be considered to be the apparent source resistance. The electrolyte resistance can be determined, however the ship to water resistance and the terminal ground resistances must be deduced as galvanic currents would make any attempt to measure them very difficult and costly.

f. Voltages of three test electrodes in the water and measured to terminal ground. The electrode materials are copper, iron, and aluminum. Measurements will be accomplished before the vessel arrives at the dock, and while the vessel is at dock.

C. CONCLUSION

It is anticipated that when sufficient information has been obtained to establish a reasonable data base, a pattern will emerge. The variety of conditions known to exist can then be modeled. It will then be possible to suggest appropriate measures to be taken for protection against the stray current hazard.

APPENDIX A

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APPENDIX B

New Technology Report

CARD (CC 1-3)	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	Approved Through January 1970
2 3	**NEW TECHNOLOGY TRANSMITTAL** (See Instructions on Reverse)	Budget Bureau No. 104-R0046
		NT CONTROL NUMBER (CC 4-11): N P C - 1 5 2 7

1. TITLE

ELECTRICAL HAZARD PROTECTION OF TANK VESSELS MOORED TO SHORE FACILITIES

2. INNOVATOR(S)

Royal G. Harrison, Thomas W. Andrews and Don H. Hoff

3. EMPLOYER (Organization and division)	4. ADDRESS (Place of performance)
Caltech/JPL	4800 Oak Grove Dr., Pasadena, Ca. 91103

5. DOCUMENTATION (Full and complete disclosure must be enclosed, the contents of which are discussed in NHB 2170.3, Documentation Guidelines for New Technology Reporting. Place an "X" to the left of those items of documentation which are available but NOT enclosed with this transmittal)

ENGINEERING SPECIFICATIONS	OPERATING MANUALS	COMPUTER TAPES/CARDS
ASSEMBLY/MFG DRAWINGS	TEST DATA	
PARTS OR INGREDIENTS LIST	ASSEMBLY/MFG PROCEDURES	

6. PREVIOUS PUBLICATION OR PUBLIC DISCLOSURE

PUBLICATION: TYPE: JOURNAL / REPORT / CONFERENCE OR SEMINAR — BY: NASA / OTHER GOVT. / CONTRACTOR

VOLUME NO. | PAGE | DATE | STATUTORY BAR ESTABLISHED (Date)

TITLE

PATENT: STATUS: APPLICATION FILED / ISSUED — NO. — DATE

7. STATE OF DEVELOPMENT

CONCEPT ONLY / DESIGN / PROTOTYPE / MODIFICATION / PRODUCTION MODEL / USED IN CURRENT WORK

8. ORIGIN (CC 12): P

9. NASA PRIME CONTRACT NO. (CC 13-23): N A S 7 - 1 0 0

10. SUBCONTRACT TIER (CC 24):

11. CONTRACTOR REPORTABLE ITEM NO. (CC 25-33): 1 5 2 7 9

For Internal Use Only

12a. CONTRACTOR/GRANTEE NEW TECHNOLOGY NOT SUBMITTED PURSUANT TO NT/PW CLAUSE PROVISION (CC 34)

13. SUBCONTRACTOR CIC (CC 35-41):

14. NT RECEIPT DATE (CC 42-47): MO 0 4 DAY 0 2 YR 8 0

RD-152(A/218)

15. PROJ. NO. (CC 48-51): - 1 4 1

16. EVALUATION ORGANIZATION (CC 52-54): N P O

17. NT FORWARDED FOR EVALUATION (Date) (CC 55-60):

18. COMMENTS: Additional material is available for a technical support package.

19. PREPARED BY	NAME AND TITLE: Jacob J. Bobrow, Patent Attorney	SIGNATURE: Jacob J. Bobrow	DATE: 6/3/80
20. APPROVED (Center TUO)	NAME: John C. Drane	SIGNATURE:	DATE:

NASA FORM 666 SEP 68 PREVIOUS EDITIONS ARE OBSOLETE.

NASA CASE NO. 15279
JPL CASE NO. 4791

JPL → NEW TECHNOLOGY DATA SHEET

1. SUBMITTED BY NAME(S)

	FIRST	INITIAL	LAST	SECTION	EXT.	SUPERVISOR	RESIDENCE AND MAILING ADDRESS
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	S.S. NO. 558-20-9923						
(2)	Royal	G.	Harrison	351	2175	R. Martin	4534 Hillard, La Canada, CA 91011
	S.S. NO. 489-28-3004						
(3)	Thomas	W.	Andrews	351	2165	R. Martin	1608 N. Altadena Dr., Pasadena, CA 91107
	S.S. NO. 550-40-2087						
(4)							
	S.S. NO.						

2. TITLE

ELECTRICAL HAZARD PROTECTION OF TANK VESSELS MOORED TO SHORE FACILITIES

3. NOVEL FEATURES

Protection of Tank Vessels carrying flammable cargoes from inadvertent electrical discharges requires obtaining data relating to the nature of such discharges. The instrumentation being developed for obtaining such data is described herein.

4. HISTORICAL DATA	DATE	LOCATION
a. CONCEPTION	12/14/79	JPL
b. DISCLOSURE TO OTHERS	12/20/79	JPL
c. FIRST SKETCH OR DRAWING	12/20/79	JPL
d. FIRST WRITTEN DESCRIPTION	1/3/80	JPL
e. COMPLETION OF MODEL OR FULL-SIZED DEVICE	5/1/80	JPL
f. FIRST TEST OR OPERATION	5/8/80	U.S. Coast Guard Ship GLACIER, Long Beach, CA.

5. NAMES OF PERSONS ACQUAINTED WITH THIS WORK

Carl Thiele

6. RESULTS OF TEST

Successful

7. APPLICATIONS (INDUSTRIAL, GOVERNMENTAL, OTHERS)

8. REFERENCE REPORTS, PUBLICATIONS AND DRAWINGS

9. JPL CHARGE NO.	10. NASA TASK ORDER NO.
764-71101-0-3510	RD-152 (A/218)

11. SIGNATURES

TECHNOLOGY UTILIZATION STAFF MEMBER	INNOVATOR(S)	DATE REPORTED
Jacob J. Bobrow	(1) Carl Thiele	May 8 '80
APPROVED: Mgr Office of Patent Counsel	(2) Don H. Hoff	5/8/80
Luther J. Speck		
APPROVED: Mgr Patents and Tech Utilization	(3) Royal G. Harrison	5-8-80
T. L. Stam	(4) Thomas W. Andrews	5-13-80

NEW TECHNOLOGY REPORT

4791 CASE NO 15279 R NO

TITLE: ELECTRICAL HAZARD PROTECTION OF TANK VESSELS MOORED TO SHORE FACILITIES

I. The Novelty

Protection of Tank Vessels carrying flammable cargoes from inadvertent electrical discharges requires obtaining data relating to the nature of such discharges. The instrumentation being developed for obtaining such data is described below.

II. The Disclosure

The Problem

Explosions and fires involving tank vessels during transfer of flammable cargoes have occurred with alarming frequency. These accidents have often resulted in loss of life and property. It is usually difficult, if not impossible, to determine the cause of the accident after the fact. Stray electric currents are thought to be the cause of sparks which could have produc ignition of explosive vapors in some accidents. The occurrence of ignition from static electrical discharges is thought to be much less likely at the tanker-terminal interface.

The United States Coast Guard has an interest in preventing such disasters. When the nature, and current and voltage characteristics of possible electrical phenomena have been established, it will be possible for the USCG to promulgate regulations or establish requirements for insuring safety of personnel and property involved in flammable cargo transfers.

The Solution

Because shipboard and dock conditions which might cause generation of stray currents and static electricity charges are very complex and variable, modaling or mathematical analysis has been of little value in the absence of some experimentally obtained data.

ELECTRICAL HAZARD PROTECTION OF TANK VESSELS MOORED TO SHORE FACILITIES

Instrumentation is being developed for obtaining such data. The instrumentation includes means for determining whether arcing actually occurs and the threshold conditions under which arcing may take place in the docking environment. The instrumentation is capable of measuring very high currents and the range of voltages which are most likely to be encountered. The means will also be capable of determining whether stray currents are direct current, pulsating direct current or have alternating current components.

Description and Explanation

Figure 1 shows a layout of the panel for the instrumentation and Figure 2 is a schematic showing the various elements. Figure 3 shows various views of the arc detector arrangement.

Switches S1 and S2 are marine battery switches capable of handling very lar currents on the order of hundreds of amperes since it is expected that the currents which will be measured will be in that current range, although the voltage will be in the 0.2 to 0.8 volt range. The source of this current is in part the galvanic interaction of the metal hull of the ship with the sea water. The electrical equipment aboard the tanker can also contribute to stray currents flowing between the tanker and the shore facilities. Thus it is possible that a very heavy current arc can be generated as the fuel transfer lines are connected between the tanker and the grounded dock.

All of the instrumentation will be enclosed in an air tight box or container which will be pressurized to 0.5 psig above ambient to prevent flammable fumes from seeping into the container. This precaution will prevent explosions within the container when the arc tests are performed.

Connection will be made from the terminals of the instrumentation to the tanker and to the shore ground. From the off shore tanker, connection will

be made by 100 feet of AWG 4/0 welding cable to provide a very low impedance connection which will be on the order of 0.005 ohm. The connection from the instrumentation to the dock will be made by a similar cable only ten feet long to provide a low impedance path on the order of 0.0005 ohm. Thus the instrument package will always be located on the dock and never on the floating tanker.

Referring to the schematic diagram, after switch S1 is closed, switch S2 can be closed to measure current. Connection to the digital voltmeter (typically a FLUKE model 8024A) is effected by closing switch S3 which places the voltmeter (and the oscilloscope, typically an NLS model MS-15) across the 0.001 ohm shunt. Current is measurable by interpreting the voltage drop across the shunt. The oscilloscope makes it possible to determine if the sensed electrical value includes an AC component.

Arc detection will be effected by use of the arc contactors shown in Figure 3. One contact is pointed and held in fixed position, but the other contact is movable under manual manipulation to induce arcing. Arcing is detected by sensing light output. The parabolic reflector surrounding the contacts collects light output and focuses the light bundle on the photodiode positioned below the reflector.

The diode output is amplified by enclosed electronics and the amplified output is used to charge a capacitor whose charge and discharge are monitored by an analog type meter. This arrangement will produce a needle indication having a sharp rise and a relatively slow decay indication on the meter.

While current and voltage could be measured using standard bonding lines, the use of the very low impedance bonding line described above is preferred because it is necessary to establish a controlled low impedance bonding line

connection that will be the same for all measurements. The instrumentation is being designed so that its use will not present any hazard to flammable cargo transfer activities. As a precaution, the instrumentation will operate on self-contained batteries.

Initial field testing was accomplished at the Long Beach Naval Yard on the U.S. Coast Guard Ice Breaker GLACIER. The voltage and currents that were measured were not of the magnitude which it is expected will be encountered with tanker vessels, but were adequate for a realistic field test of equipment and personnel. During this first test, reference measurements were made using zinc, steel and copper electrodes immersed in the sea water. The voltages and currents that were measured provided a check on the operation of the equipment and the methods of attachment of the electrical cables between ship and shore.

TITLE: ELECTRICAL HAZARD PROTECTION OF TANK VESSELS MOORED TO SHORE FACILITIES

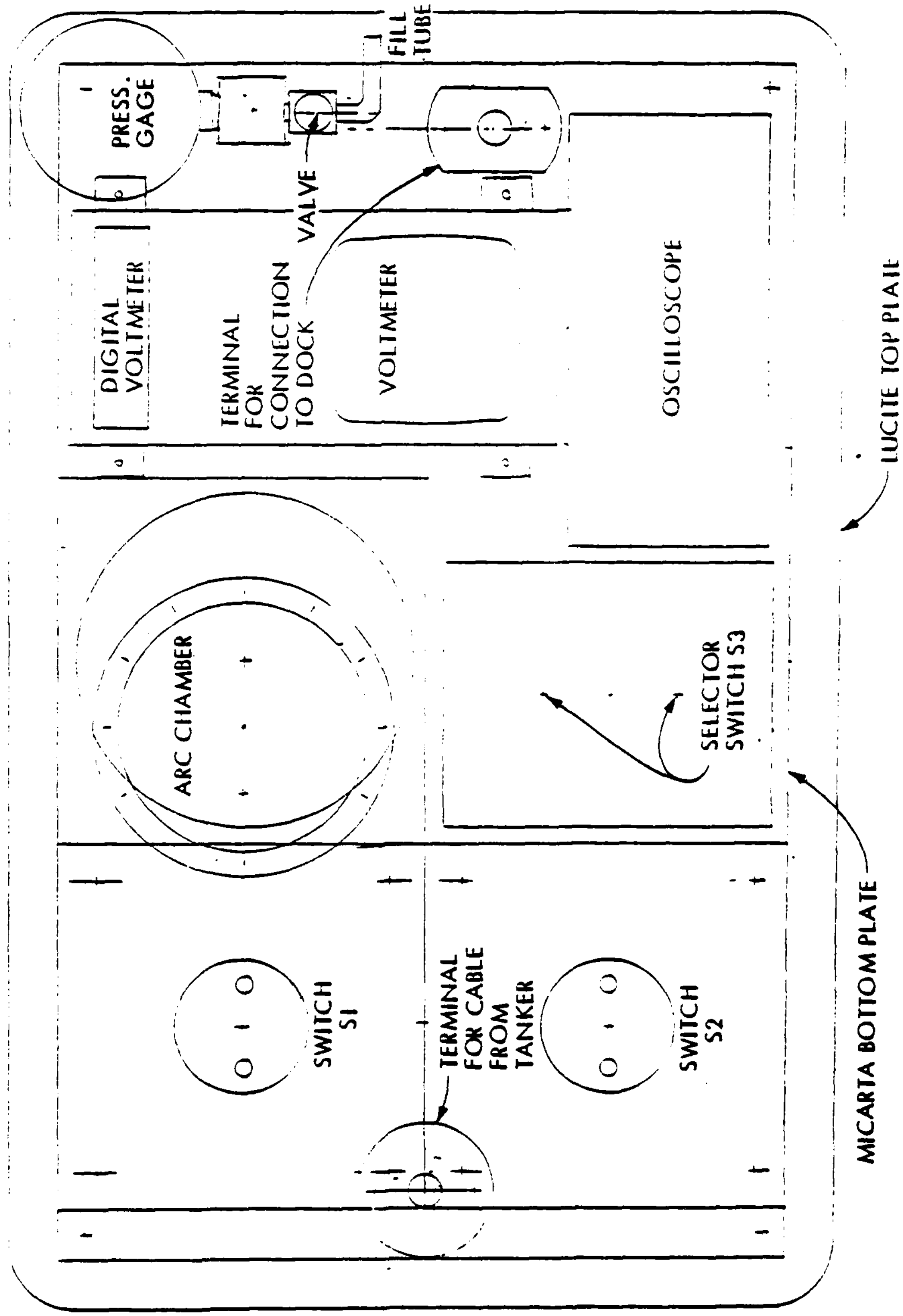
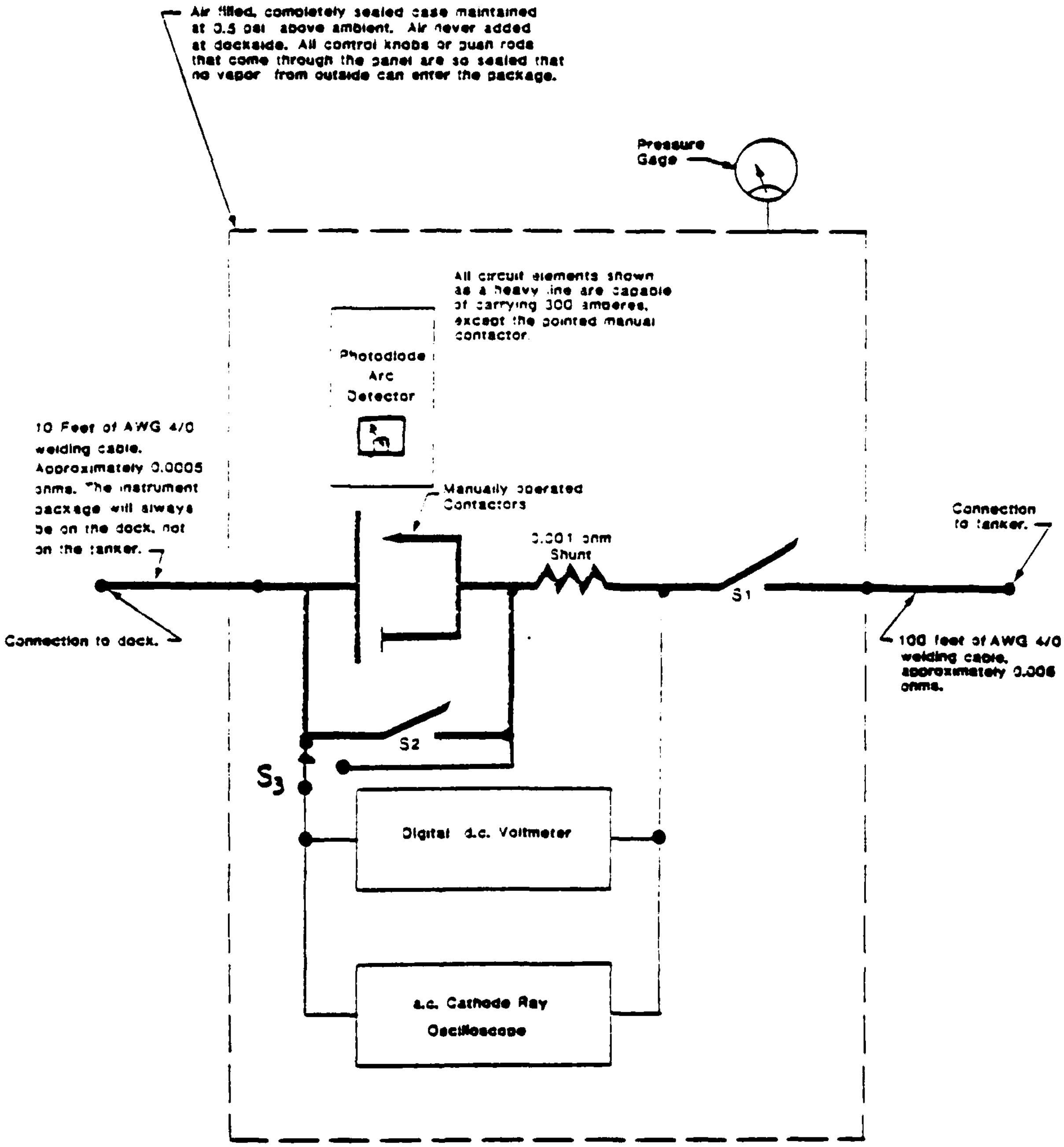


FIGURE 1

TITLE: ELECTRICAL HAZARD PROTECTION OF TANK VESSELS MOORED TO SHORE FACILITIES



Open circuit measurements S_1 closed, S_2 open.
Closed circuit measurements S_1 closed, S_2 closed.
Arc detection S_1 closed, S_2 open, operate contactors.

FIGURE 2

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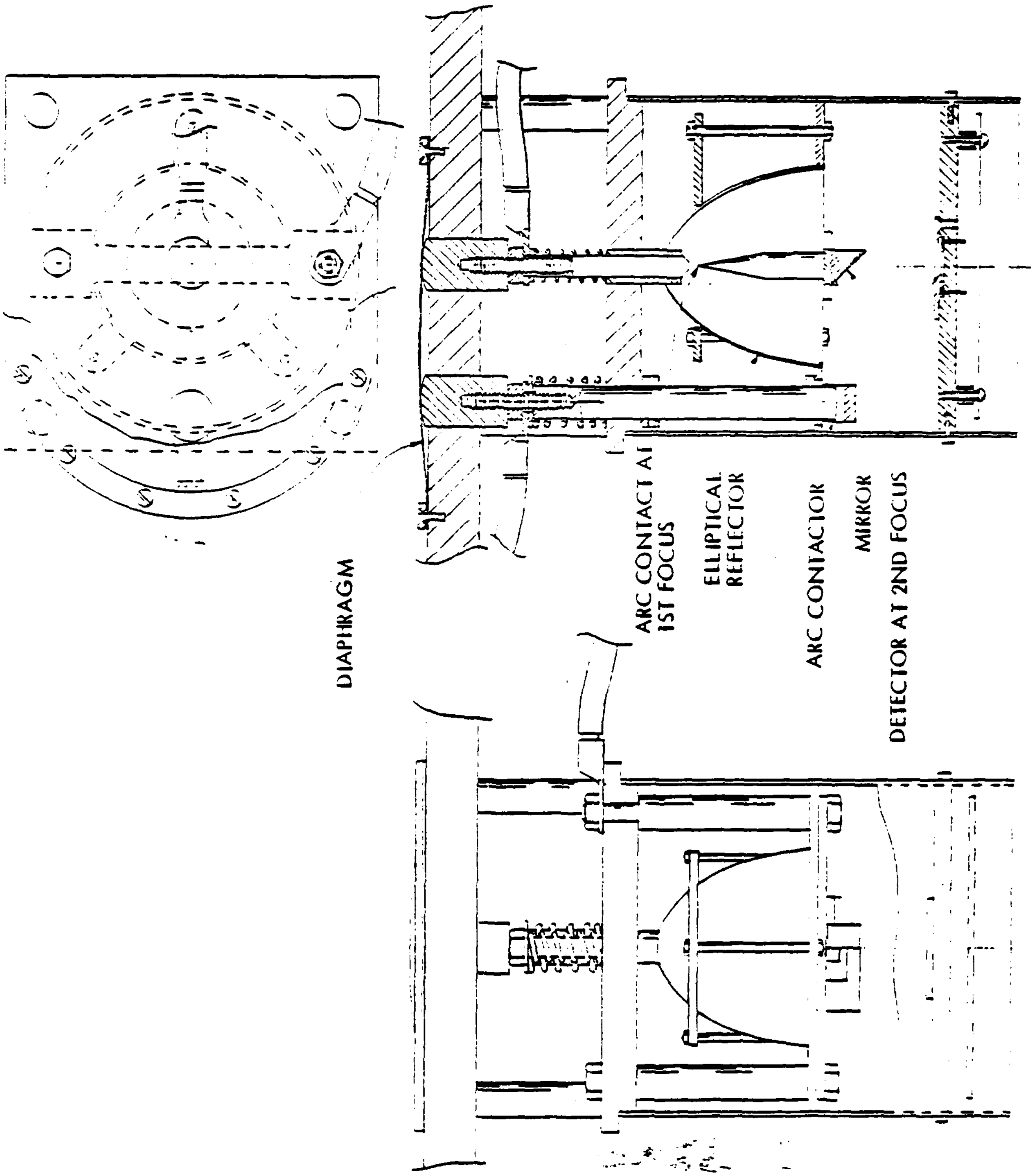

ARC DETECTOR
FIGURE 3

TITLE: ELECTRICAL HAZARD PROTECTION OF TANK VESSELS MOORED TO SHORE FACILITIES

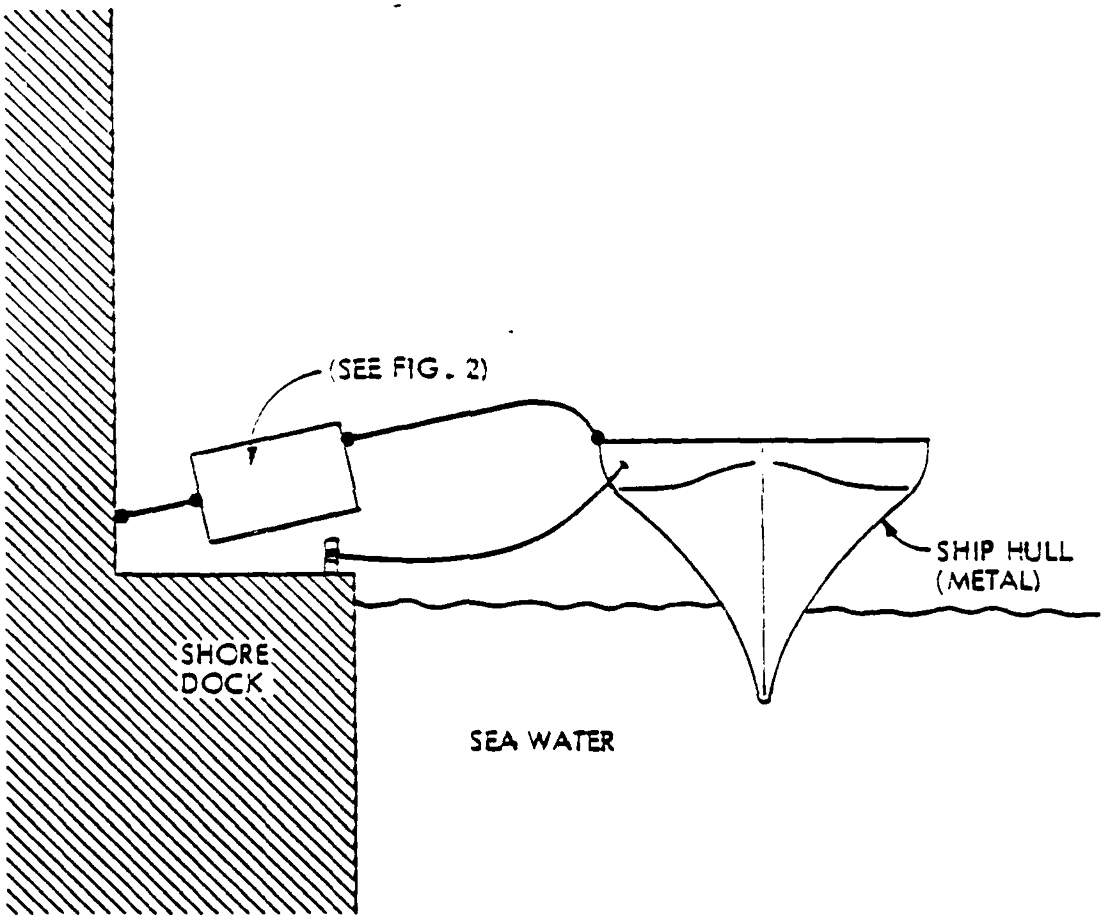

FIGURE 4